Patent Claims

1. Method for determining the image quality of an optical imaging system that substantially comprises the following subassemblies: illumination system, including light source, sample holder with sample, imaging optics, and at least one spatially resolving detection device, comprising the following method steps:

- adjusting the subassemblies relative to one another in such a way that it is possible to image a sample on the detection device;
- recording a plurality of images of the sample from different adjusting or reference planes near the focus plane, wherein the detection device is adjusted relative to the image plane, the sample is adjusted relative to the object plane, or the objective is adjusted relative to the sample;
- improving the image quality by means of image processing, particularly to reduce noise, to compensate for local variations in sensitivity of the detection device, and to center the intensity centroids respectively on a predetermined location in the images;
- computational linking of spatially resolved image information, of adjustment values and system variables relating to the optical imaging system, and of information concerning the sample with the aim of determining characteristic numbers that are characteristic of the wavefront deformation caused by the imaging system; and
- outputting the characteristic numbers and associating them with the imaging system as equivalent for the image quality,

wherein Zernike coefficients are outputted as characteristic numbers, each one being associated with a reference plane.

2. Method according to claim 1, characterized in that the characteristic numbers are determined in a first step initially by analytic evaluation and, in a subsequent second step, by further iterative processing of the results from the first step until a given termination criterion is reached.

3. Method according to claim 2, characterized in that the determination of Zernike polynomials up to a given order is carried out with the analytic evaluation of the image information.

4. Method according to claim 2 or 3, characterized in that the determination of

Zernike coefficients is carried out with the iterative evaluation of the image information based on methods in which every wave surface from the image stack of the sample is considered as a unit, or a pixel-by-pixel evaluation is carried out, and wherein the determined Zernike coefficients correspond to the outputted characteristic numbers.

5. Method according to one of the preceding claims, characterized in that the change of reference plane always takes place in the object space, i.e., by changing the distance of the sample relative to the object plane.

6. Method according to claim 5, characterized in that the change of reference plane is carried out in predetermined increments.

7. Method according to claim 5 or 6, characterized in that the number of variables in the iterative step of the evaluation is increased, preferably doubled, in relation to the preceding, analytic step.

8. Method according to one of the preceding claims, wherein the sample has a pinhole with a diameter d_{PH} = 300 nm, illumination light with the wavelength of 248 nm is used, the pixel size at the sample is 45 nm, the numerical aperture of the imaging system is 0.2, the illumination aperture corresponds to the numerical aperture of the imaging system, the illumination of the sample is carried out with partially coherent light at $\sigma \approx 0.8$, the diameter of the Airy disk in the image is 1.512 µm, the depth of focus is 6.2 µm, the defocusing from image to image is carried out within the depth of focus range at ±1 RE (RE = Rayleigh unit), ±3 RE and ±0.8 RE or ±6.2 µm, ±18.6 µm and ±5 µm, and an odd-number quantity of images is predetermined, preferably a quantity of 7, 11 or 21 images.

9. Method according to one of the preceding claims, characterized in that a deconvolution of the image information is provided depending upon the size of the pinhole in the sample in order to exclude the influence of the pinhole size on the results

10. Method according to one of the preceding claims, characterized in that the influence of the pupil of the imaging system is taken into account in the evaluation of the image information, preferably by means of a pupil image that is obtained using a Bertrand system.

11. Method according to one of the preceding claims, characterized in that the pupil function is predetermined with respect to apodization.

12. Method according to one of the preceding claims, characterized in that a plurality of detection devices are arranged at different distances to the image plane and the images are accordingly recorded from the different reference planes at the same time or also successively in time with a corresponding control.

13. Method according to one of the preceding claims, characterized in that a plurality of samples arranged adjacent to one another or a sample with a plurality of objects arranged adjacent to one another is positioned in the sample holder and information concerning the image quality is accordingly determined simultaneously in relation to the corresponding positions in the visual field of the imaging system, and/or simultaneous measurements are carried out with a plurality of different wavelengths in order to detect dispersive or wavelength-dependent effects.

14. Method according to one of the preceding claims, characterized in that samples with binary objects, i.e., pure amplitude objects, preferably in the form of round or square pinholes, are provided.

15. Method according to one of the preceding claims, characterized in that the image quality is determined in an automatic process beginning with the positioning of a sample until the output of the characteristic numbers.

16. Method according to one of the preceding claims, characterized in that an exposure device is provided which ensures an optimal illumination of the sample depending on the change of the reference plane, and the signal-to-noise ratio is accordingly optimized in the images.

17. Method according to one of the preceding claims, characterized in that a laser beam having a beam waist in the object plane is provided for illuminating the sample in order to achieve a low sigma value and a Gaussian intensity distribution in the pupil.

18. Method for determining the influence of different samples on the amplitude distribution and phase front distribution of the illumination light, characterized by the following method steps:

- determining the wavefront deformation characterizing the optical imaging system in the form of characteristic numbers according to claims 1 to 17 based on a sample with known, defined optical characteristics;
- exchanging the known sample for a sample which is to be examined and

whose optical characteristics are still unknown;

- determining the wavefront deformation again in the form of characteristic numbers according to claims 1 to 17 under the influence of the sample to be examined;
- determining the influence of the sample to be examined based on the differences of the characteristic numbers for the image quality under the influence of the defined sample and the characteristic numbers for the image quality without the influence of the sample to be examined;
- determining the characteristics of the sample to be examined from the difference of the characteristic numbers.

19. Method according to claim 18, characterized in that the image information obtained with the initially still unknown sample is subjected to post-processing in which the characteristics of the imaging system are separated from the characteristics of the sample that was used to characterize the imaging system, and the specific device characteristics are accordingly corrected at the same time when imaging the unknown sample.

20. Method according to claim 19, characterized in that the influence of specific sample characteristics, particularly the size of an observed object, is also corrected from the image information during the post-processing of the image information at the same time.

21. Method according to claim 19 or 20, characterized in that in particular the influence of a stepper in microlithography is factored into the characteristics of a sample image again by convolution.

22. Method according to claim 18 or 19, characterized in that lithography masks, particularly masks with a phase-shifting effect, are provided as samples.